ANL/IPNS/CP-96405

Neutron Beam Characterization at the Intense Pulsed Neutron Source

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January 9, 1998

1 Introduction

The Intense Pulsed Neutron Source (IPNS) at Argonne National Laboratory is a spallation neutron source dedicated to materials research. Its three cryogenic methane moderators provide twelve neutron beams to fourteen neutron scattering instruments and test facilities. The moderators at IPNS are of cryogenic methane (CH_4); one of liquid methane at 100 K, and two of solid methane at 30 K. These moderators produce intense beams of both cold and thermal neutrons. The moderators are each of a different physical configuration in order to tailor their performance for the instruments and facilities that operate on the neutron beams. As part of the ongoing operation of IPNS, as well as new enhancements to the target, moderator, and reflector systems, we have performed experiments characterizing the energy and time distribution of neutrons in the various beams. These measurements provide absolutely normalized energy spectra using foil activation techniques joined with time-of-flight measurements, and energy-dependent time distributions using a time-focused crystal analyzer.

The IPNS accelerator system delivers 14 μA of 450 MeV protons, in 100 ns pulses at 30 Hz, to a target composed of water-cooled depleted uranium disks. The solid methane "H" moderator is 100 by 100 by 45 mm in size, centerline poisoned with 0.25 mg/mm^2 gadolinium, and decoupled from the graphite reflector with 0.5 mm of cadmium. The liquid methane "F" moderator, which is viewed from both faces, is also 100 by 100 by 45 mm in size, gadolinium poisoned 16 mm below each of the two viewed surfaces,

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and decoupled from the graphite reflector with cadmium. The solid methane "C" moderator has a re-entrant "grooved" geometry. The moderator is 100 by 100 by 80 mm overall, with 40 mm deep 12 mm wide horizontal grooves in the viewed surface. These grooves cover 50% of the viewed surface area. The "C" moderator is unpoisoned, but is decoupled from the graphite reflector with 0.5 mm of cadmium.

2 Experimental Methods

A combination of foil activation techniques and time-of-flight measurements provided the absolutely normalized energy spectra of the various neutron beams. A low-efficiency transmission monitor in the neutron beam gives the spectral shape of the distribution, which is then normalized using an absolute monitor efficiency obtained from a simultaneous cadmium-difference gold foil activation. This efficiency is

$$\eta = \lambda \cdot \frac{mL_D}{2hA} \cdot \frac{L_\mathrm{D}^2}{L_\mathrm{f}^2} \cdot \frac{N_\mathrm{c}N_\mathrm{b}}{N_\mathrm{c}R_\mathrm{b}(1-\gamma) - N_\mathrm{b}R_\mathrm{c}} \int_{t_\mathrm{min}}^{t_\mathrm{max}} (1 - e^{-\Sigma_\mathrm{Cd}(t)t_\mathrm{Cd}} - \gamma)\sigma_\mathrm{Au}(t) \frac{C(t) - B}{t} dt, \tag{1}$$

where λ and m are the wavelength and mass, respectively, of the neutron, L_D and L_f are the path lengths from the moderator to the detector position and to the foil position, respectively, h is Planck's constant, A is the active area of the detector, N_c (N_b) and R_c (R_b) are the number of atoms and the saturation activity of the cadmium-covered (bare) foils, respectively, t is the neutron time-of-flight, and γ is the (roughly constant) attenuation of the cadmium cover at energies greater than the cadmium cutoff,

$$\gamma = 1 - e^{-\Sigma_\mathrm{Cd}t_\mathrm{Cd}}\Big|_{10\ \mathrm{eV}}. \tag{2}$$

The integral in Equation 1 extends from a short time-of-flight corresponding to neutron energies well above the 4 eV gold resonance, to a long time-of-flight limited by the source pulsing frequency. The monitor counting rate per unit time-of-flight is $C(t)$, and B is a constant background counting rate, independent of time-of-flight.

A time-focused crystal analyzer (TFXA) measures the energy-dependent time distribution of the neutron beams. This instrument[1] arranges a crystal analyzer and a detector at positions and angles relative to the moderator surface such that the energy, spatial, and angular distributions of the neutron beam do not contribute to the time resolution of the measurement. The detector then records time-of-flight data for each of the Bragg reflections of the crystal analyzer. Our TFXA uses the 111 reflections from a hot-pressed germanium crystal cut perpendicular to the 110 planes maintained at about 10 K. Neutrons scattered through 120° strike a detector tilted at 73° relative to the neutron beam. Time focusing further requires that the crystal face be tilted at an angle of 5.3° relative to the incident neutron beam, and that the incident and scattered flight path lengths have a ratio of 10:1. This focusing condition applies to neutron beams at an angle of 18° from perpendicular to the viewed moderator face.

3 Results

Typical results of the above-described measurements appear in Figure 1 (absolute beam intensity) and Figure 2 (pulse shape), taken on the liquid methane F moderator. Beam intensity measurements extend from the source pulsing frequency imposed lower limit, typically around 1 meV, to 10 eV. Pulse shape measurements extend from 2.5 meV to 1 eV. Limitations of space prevent including further results here; we will more completely present them at the ICANS XIV conference, to be held in Starved Rock, Illinois, 12-19 June 1998.

4 References

1. K. F Graham, J. M. Carpenter, *Nuclear Instruments and Methods,* **85** (1970) 163.

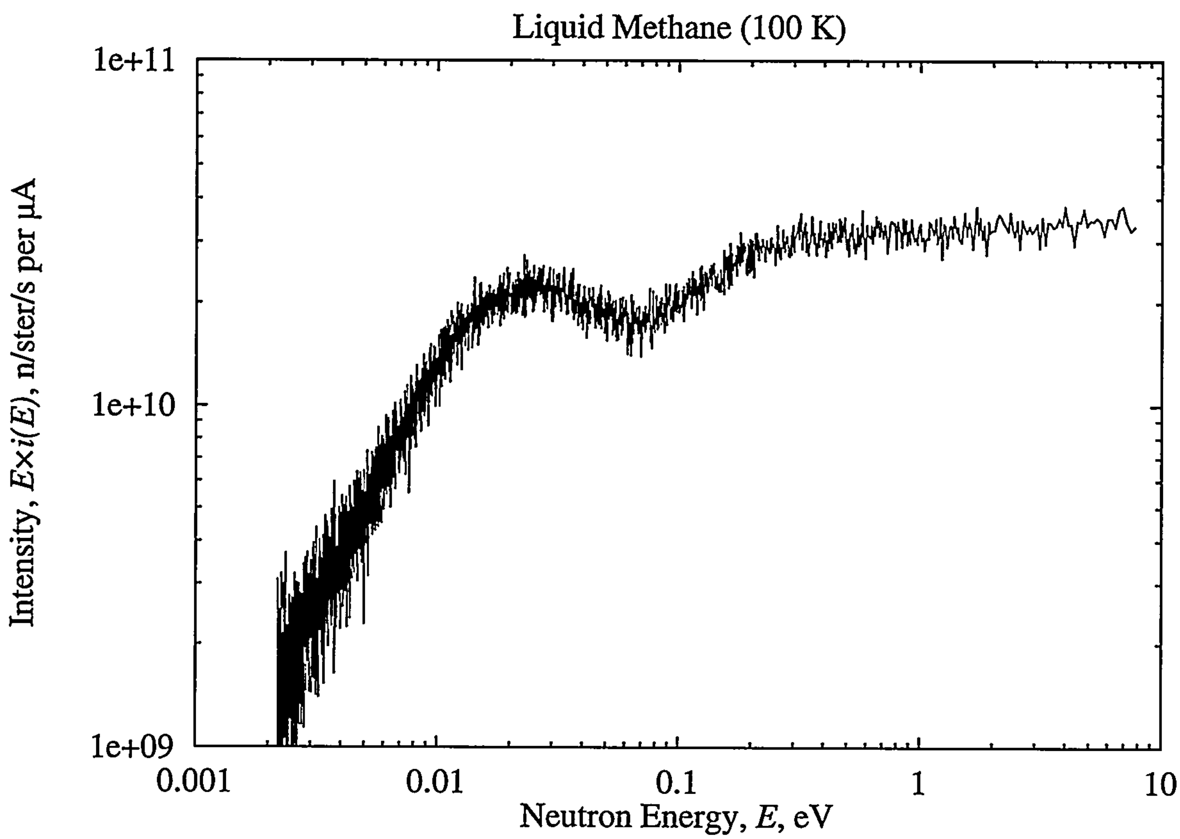

Figure 1: Absolute spectral intensity as measured on GPPD from a 100 K liquid methane moderator.

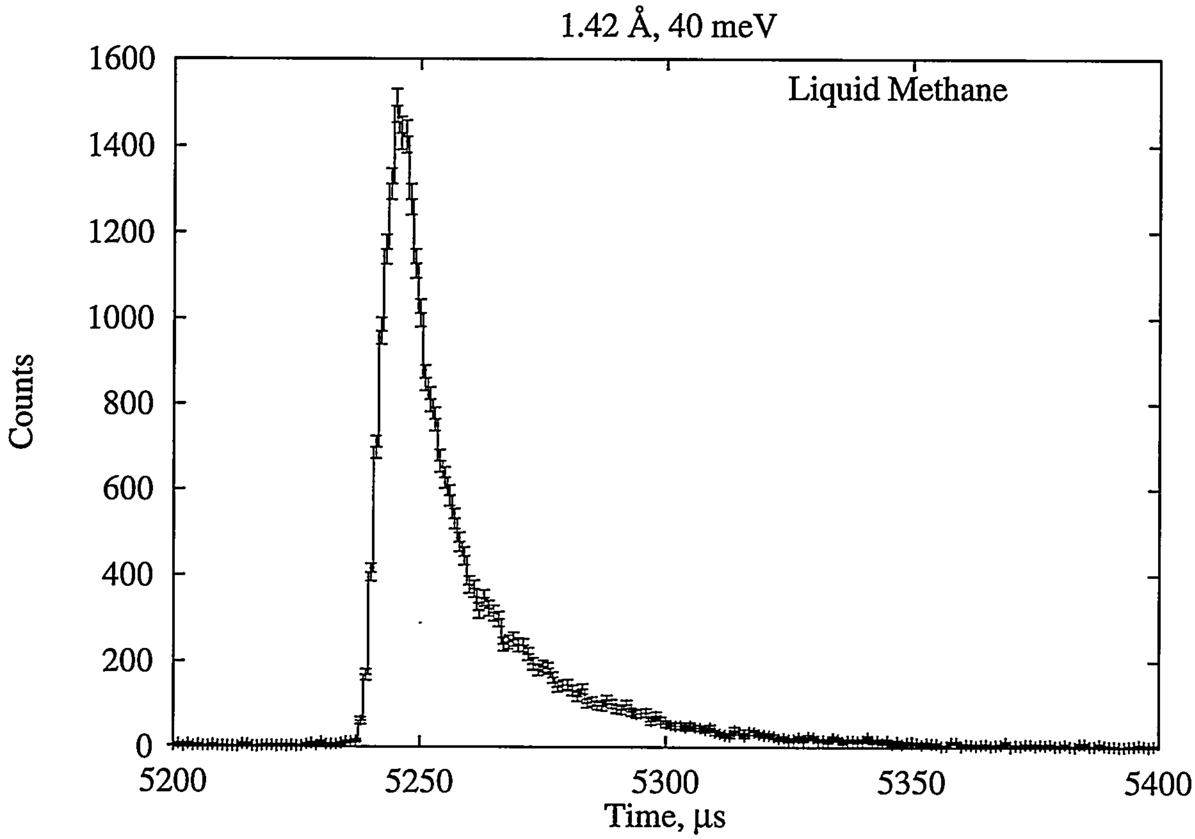

Figure 2: Time distribution of 40 meV neutrons as measured on a 100 K liquid methane moderator.